

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE****Application of**

**Applicants** : Mathias et al.  
**Serial No.** : 10/720,631  
**Filed** : November 24, 2003  
**Title** : IMPROVED PROTON EXCHANGE MEMBRANE FUEL CELL  
**Docket No.** : II-205755  
**Examiner** : S. Kalafut  
**Art Unit** : 1745

**Commissioner for Patents**  
**P.O. Box 1450**  
**Alexandria, VA 22313-1450**

**Sir:**

**DECLARATION OF MARK MATHIAS**

Mark Mathias, one of the applicants in the above-identified patent application, declares as follows:

1. I received a BS Degree in Chemical Engineering from Virginia Tech in 1982. I received a PhD degree in Chemical Engineering from Univ. of Wisconsin-Madison in 1987. I have been employed by General Motors since 1998, and I have been working the area of proton exchange membrane fuel cells since 1998. I am a member of the Electrochemical Society, have published about 15 peer-reviewed articles (6 on fuel cells), have been awarded about 12 US patents (3 on fuel cells), and was chosen by my colleagues in the fuel cell academic community to chair the Fuel Cell Gordon Conference in 2003.

2. I am familiar with this application as well as the Office Action mailed December 28, 2005, including the rejections made by the Examiner therein. I am also familiar with the

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references cited by the Examiner in that Office Action including U.S. Patent Nos. 4,551,220 to Oda, and 6,261,711 to Matlock.

3. The water vapor permeance of several commercially available materials which are used in proton exchange membrane fuel cells, as well as a developmental product, are shown in Table 7. The Toray material is made of carbon fiber bound with a carbonized phenolic resin. All four Toray samples (Toray 030, 060, 090, and 10T) have a bulk density of 0.45 gm/cm<sup>3</sup> and porosity of 0.70. There was no PTFE added. Only the thickest of the Toray samples had water vapor permeance value within the claimed range, while the other samples did not.

4. The water vapor permeance of 500 micron layer of free air at 80°C and 1 atm (not containing any porous structure) is  $4.8 \times 10^{-4}$  g/(Pa s m<sup>2</sup>). The value of the water vapor permeance of a porous layer can be estimated by adjusting this using the actual thickness of the layer and the porosity of the structure:

$$R_{DM} = \left( \frac{\epsilon}{\tau} \right) \left( \frac{500}{\delta_{DM}} \right) 4.8 \times 10^{-4} \frac{\text{g}}{\text{Pa} \cdot \text{s} \cdot \text{m}^2}$$

where  $R_{DM}$  is the water vapor permeance of the diffusion layer,  $\epsilon$  is the porosity of the layer,  $\tau$  is the tortuosity, and  $\delta_{DM}$  is the thickness of the layer in microns. Tortuosity is the distance a molecule has to travel as it diffuses through a material divided by the thickness of the material. The tortuosity was assumed to be 1 based on the structures that Oda proposes. Thus, the water vapor permeance of the materials described in the Oda patent can be estimated at the upper and lower ranges of the porosity, and various thicknesses.

Thickness ( $\delta_{DM}$ , microns)	Porosity ( $\epsilon$ ) of 0.4	Porosity ( $\epsilon$ ) of 0.95
20	$4.8 \times 10^{-3}$ g/(Pa s m <sup>2</sup> )	$1.1 \times 10^{-2}$ g/(Pa s m <sup>2</sup> )
30	$3.2 \times 10^{-3}$ g/(Pa s m <sup>2</sup> )	$7.6 \times 10^{-3}$ g/(Pa s m <sup>2</sup> )
300	$3.2 \times 10^{-4}$ g/(Pa s m <sup>2</sup> )	$7.6 \times 10^{-4}$ g/(Pa s m <sup>2</sup> )
500	$2.0 \times 10^{-4}$ g/(Pa s m <sup>2</sup> )	$4.6 \times 10^{-4}$ g/(Pa s m <sup>2</sup> )

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Thus, most of the values from Oda are higher than the claimed range of  $3.2 \times 10^{-4} \text{ g}/(\text{Pa s m}^3)$ .

5. Porosity can be calculated from the bulk density, and visa versa.

$$\varepsilon = 1 - \frac{\rho_{\text{bulk}}}{\rho_{\text{real}}}$$

where

Porosity  $\varepsilon = \text{cm}^3$  of open volume per  $\text{cm}^3$  of porous material (including solid and open volume)

Bulk Density  $\rho_{\text{bulk}} = \text{gm of material per cm}^3$  of porous structure (including solid and open volume)

Real Density  $\rho_{\text{real}} = \text{gm of material per cm}^3$  of solid material (including only solid volume)

In diffusion media structures, the real density of the materials is about  $2 \text{ gm}/\text{cm}^3$  since this is the value for both carbon and PTFE. By increasing the amount of PTFE in the structure, the bulk density is increased (by replacing open volume with solid material) and at the same time the porosity is decreased.

The declarant further states that the above statements were made with the knowledge that willful false statements and the like are punishable by fine and/or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of this application or any patent resulting therefrom.

Date: MARCH 27, 2006

Mark Mathias  
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